Triboson Studies using Madgraph

Jenny Holzbauer and Mandy Rominsky
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Technical Decisions and Comments

- Studying the processes WWW, WWZ and WZZ
- Using Madgraph plus Pythia plus Delphes
  - This is easy to use and install
  - Avoids proprietary MC, etc- currently using default cards, will switch to snowmass LHC card and settings after meeting
- Using hadron colliders from wiki (13, 30 and 100 TeV)
- In current phase, neglecting backgrounds and uncertainties, but these can be added in later
- Looking at leptonic final states only for now
  - Most plots generated for muons and electrons only- will comment on taus near end of talk

EWdim6

- Use dimension 6 effective field theory
- In Magraph (import model EWdim6)
- Couplings can be turned on or off via
  - customize_model --save newmodelname
  - Import model EWdim6-newmodelname
- For plots today (unless noted), only Cw is non-zero, and it is set to 5
  - In any case, only one coupling is non-zero at a time
- More info: see Celine's talk

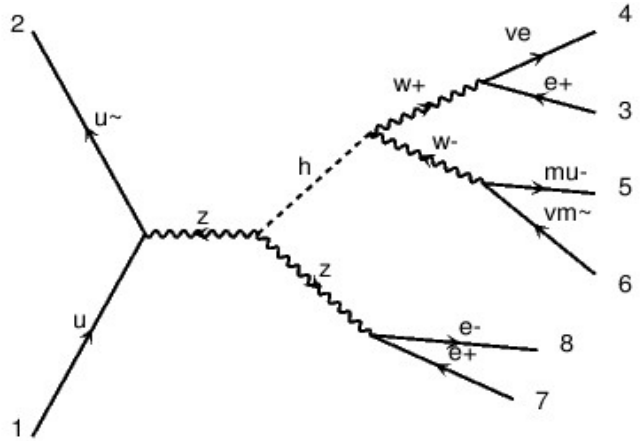


diagram 2 NP=0, QCD=0, QED=6

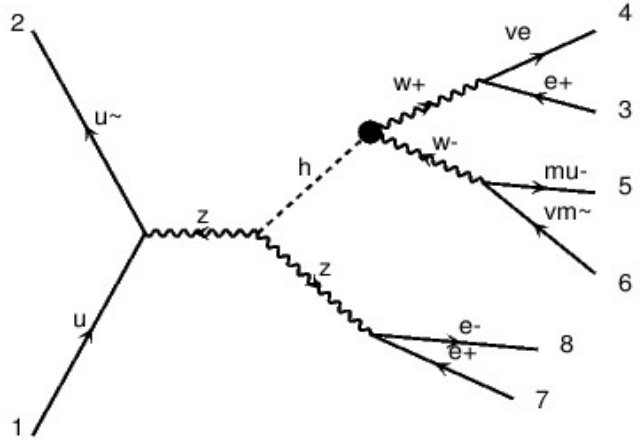
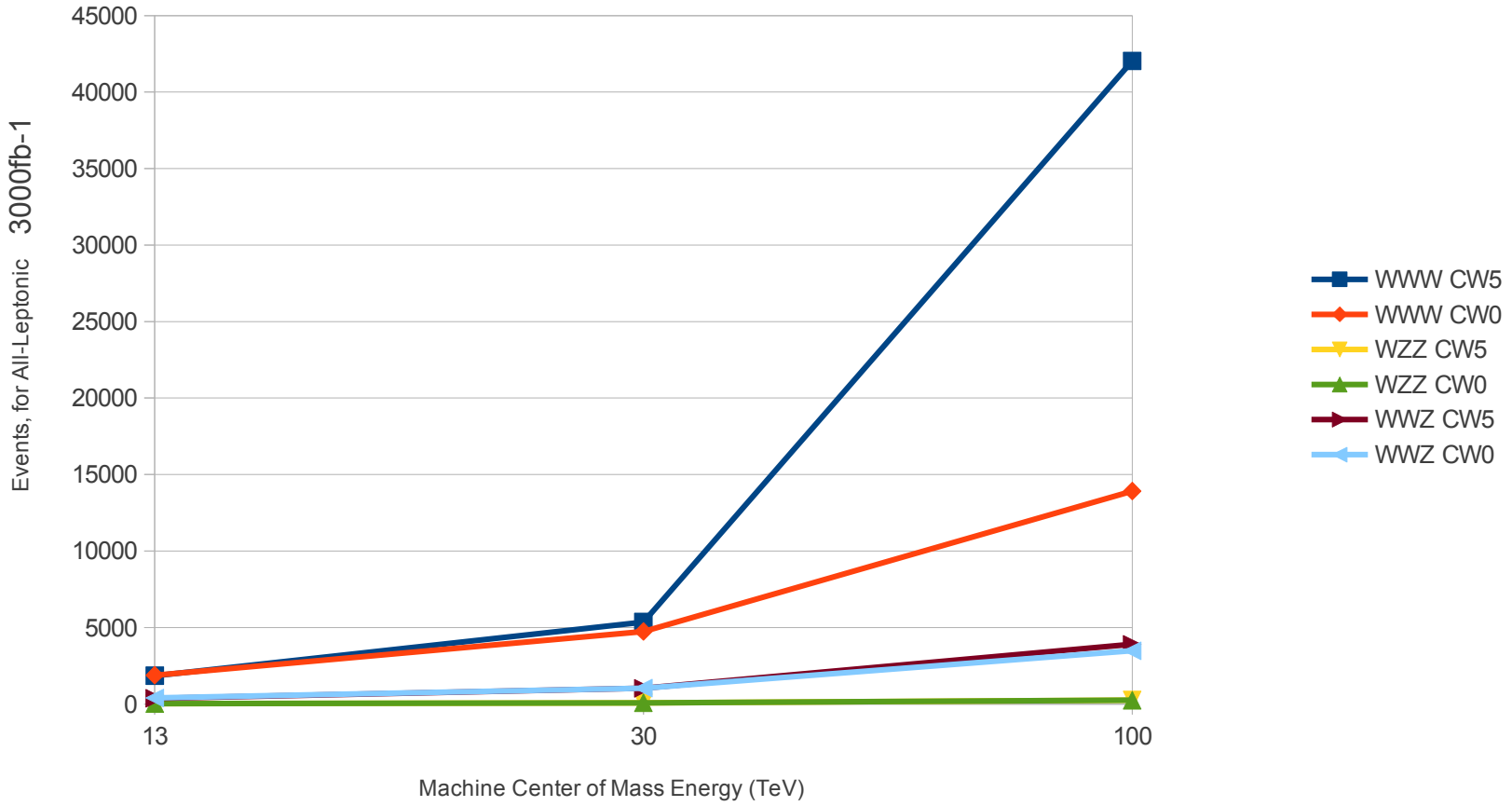


diagram 4 NP=2, QCD=0, QED=5

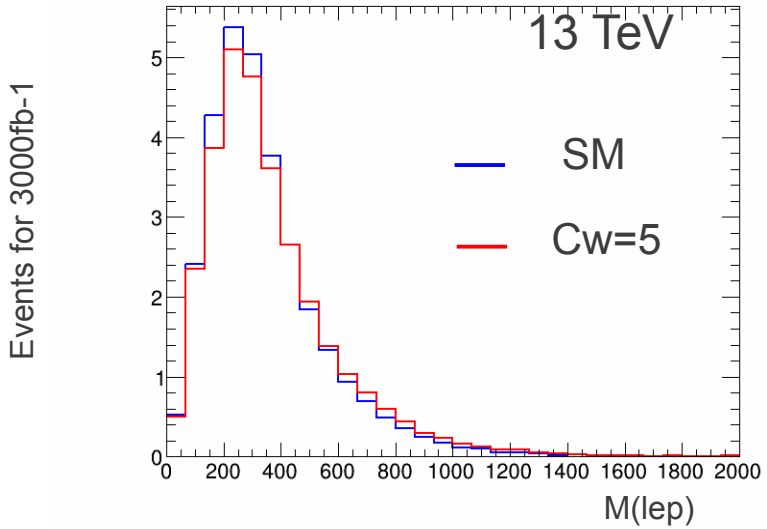
Events for Machines at Different Center of Mass Energies

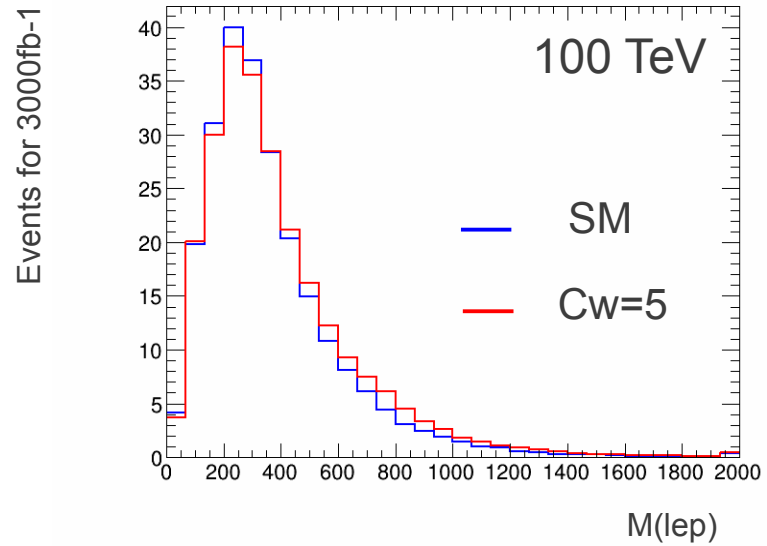
- WWW SM and EWdim6 Cw=5 cross-sections (Madgraph) diverge around 50 TeV while other processes diverge slightly



Example of WZZ Anomalous Couplings

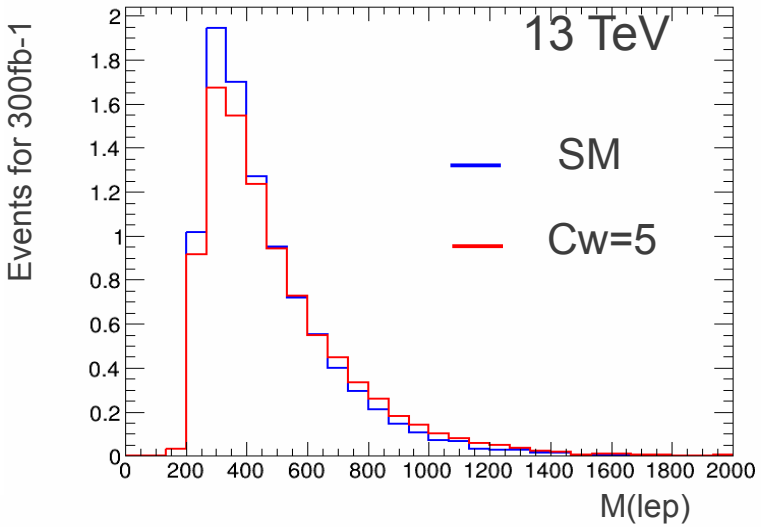
- Shows invariant mass of the leptons for SM (blue) and EWdim6 with the Cw coupling set to 5 (red)
- 50,000 generated events
- Require at least 2 leptons
  - There are a number of backgrounds with 2 leptons though, so these plots are overly optimistic
- Clearly different shapes for SM and EWdim6
- However, event rate is very small for WZZ

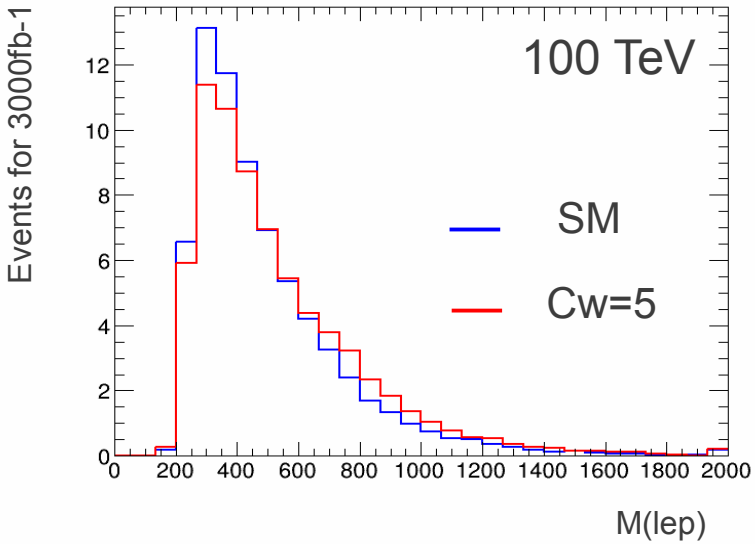




Example of WZZ Anomalous Couplings, More Realistically

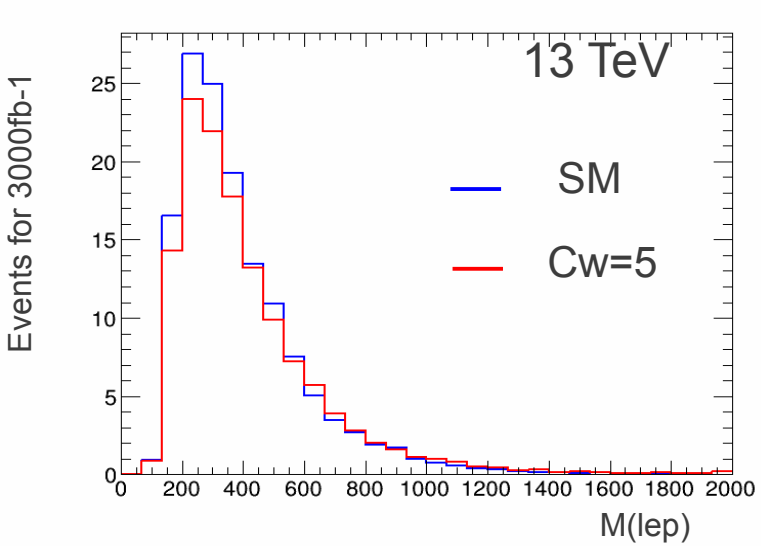
- 50,000 generated events
- Require exactly 5 leptons
- Smaller rate than previous slide, but fewer processes that have 5 lepton final states which contribute to background

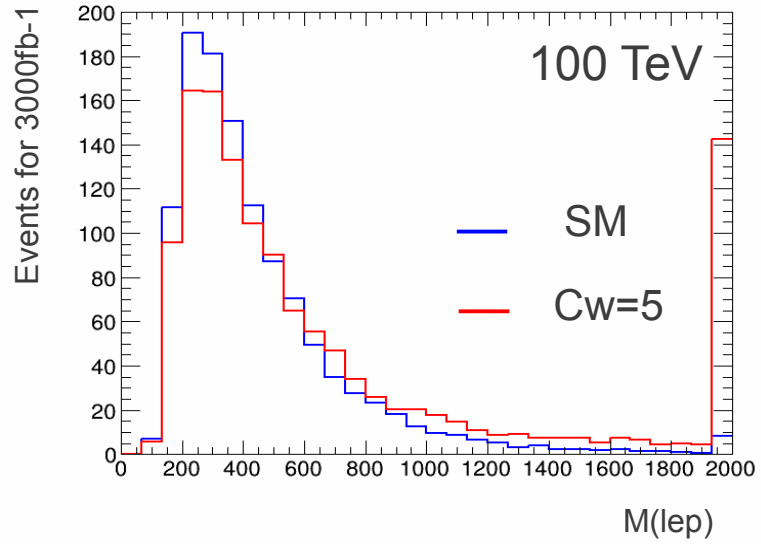




Example of WWZ Anomalous Couplings

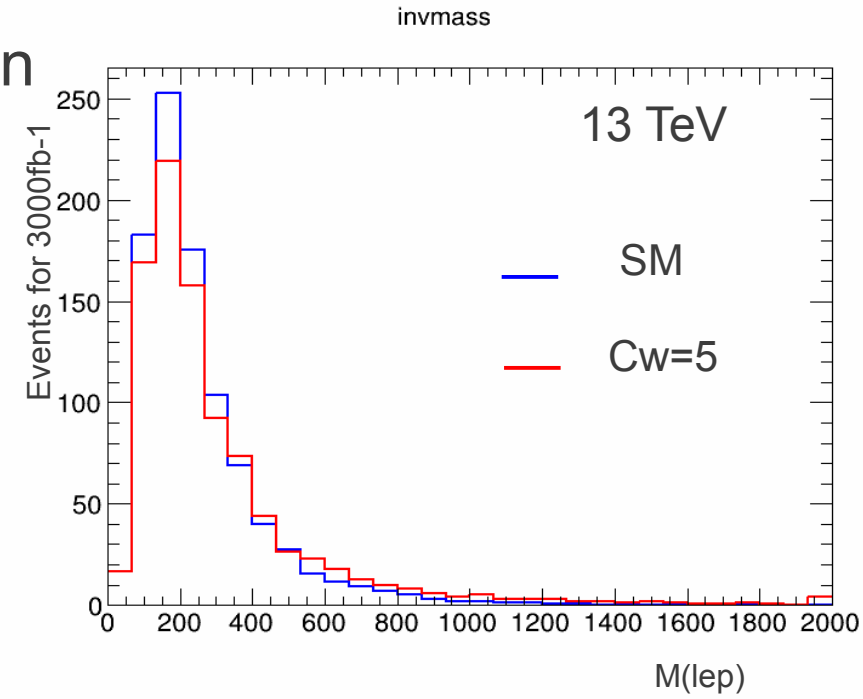
- 50,000 events
- Require exactly 4 leptons
- WWZ has the middle cross-section (from Madgraph) of the three diboson processes
- Probably will see more background events, along with more signal





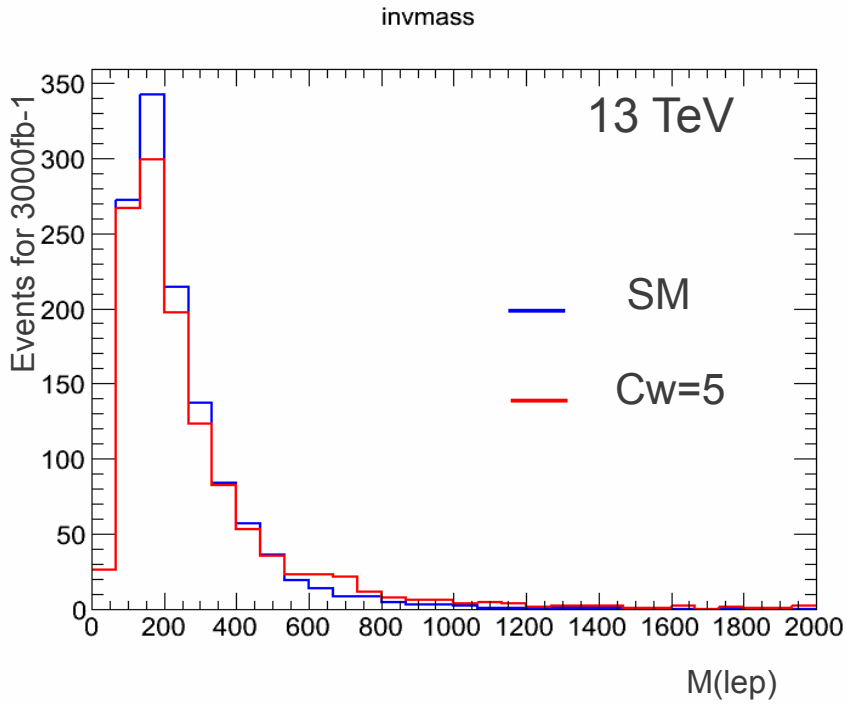
Example of WWW Anomalous Couplings

- WWW has the biggest cross-section (from Madgraph) of the three diboson processes
- 3 lepton final state
  - More background issues, mis-reconstructed ttbar, WZ
- 10,000 – 20,000 events
- Require exactly 3 leptons



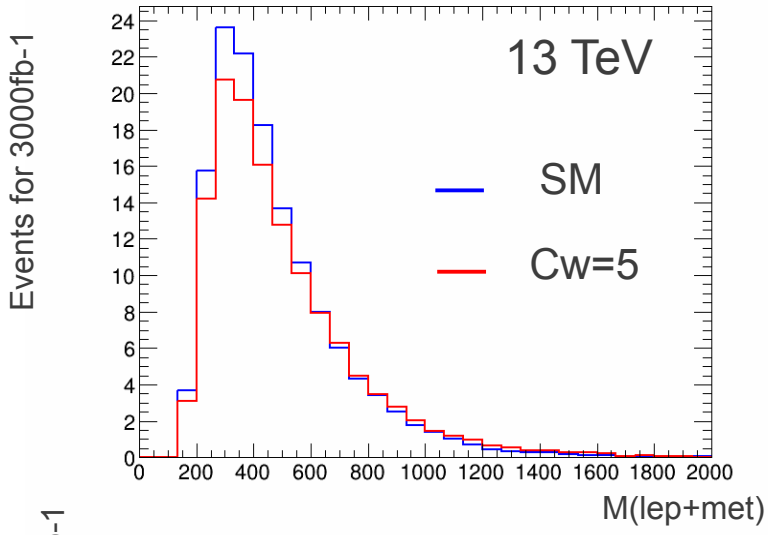
Example of WWW Anomalous Couplings Including Tau's

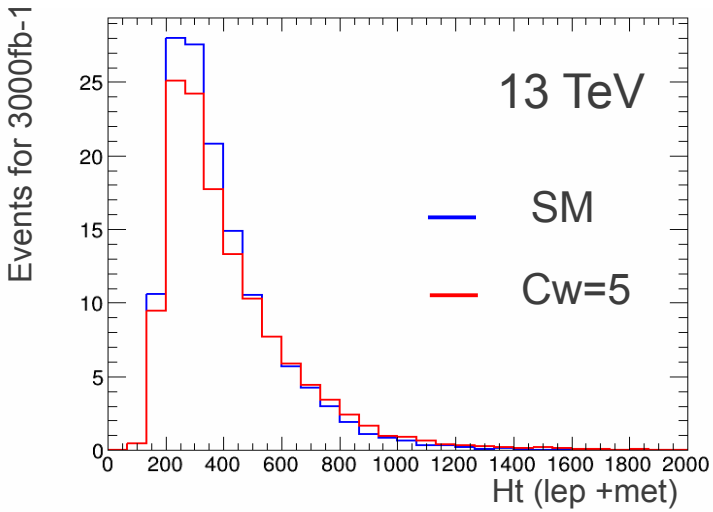
- Including tau's in particular enhances the 2 lepton bin, though also some contribution to the 3 lepton bin
- 20,000 events
- Require exactly 3 leptons
- For consistency with last slide, the lepton number requirement and invariant mass variable only use muons and electrons

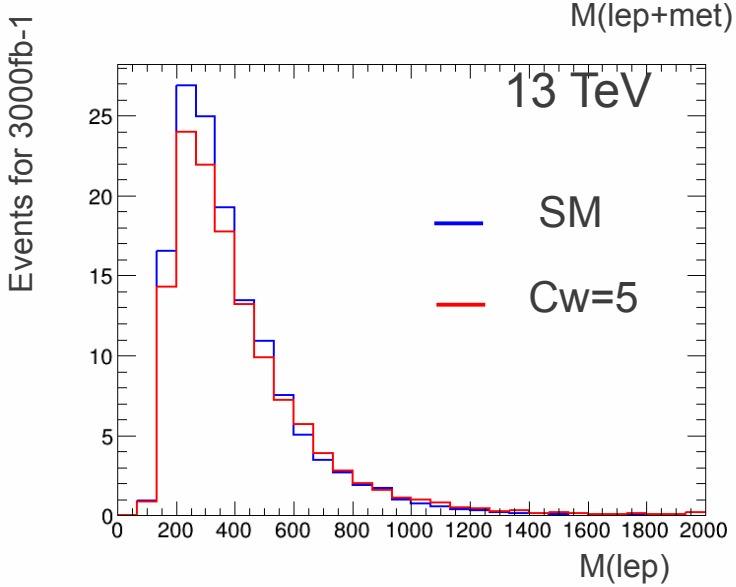


Other Discriminating Variables

- Used inv. mass of leptons = mu + el
- But can also try to include Missing Et
  - Invariant mass, but including a met vector, using pz = 0
  - Pt sum for leptons and Missing Et
- Plots are for WWZ with 4 leptons

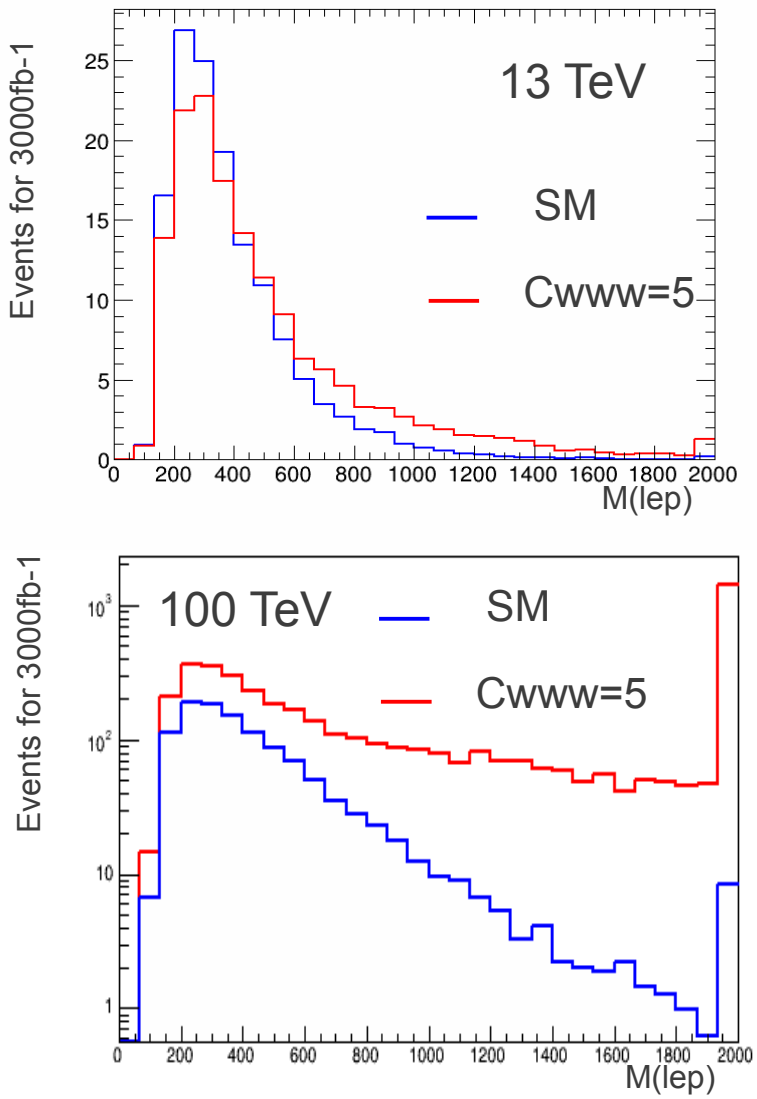






Example of WWZ Anomalous Couplings for Cwww

- 50,000 events
- Require exactly 4 leptons
- Cwww has larger impact than Cw
- No impact from Cb = 5



Summary

- We are beginning to study triboson processes WWW, WWZ, and WZZ
- Even with the new proposed machines, cross-sections are small and analyses can be challenging for leptonic final states
- Still need to consider semi-hadronic final states, backgrounds, systematic uncertainties, and additional machines, and finish evaluating Cwww, etc.

Run Commands Used

If EWdim6: import model EWdim6-cwonly

define w = w+ w-

generate p p > w w w, w+ > l+ vl, w- > l- vl~

For taus:

define lall+ = l+ ta+

define lall- = l- ta-

p p > w w w, w+ > lall+ vl, w- > lall- vl~

output dirname

Close, then modify dirname/Cards/param_card.dat so cw is 5 (for EWdim6) and dirname/Cards/run_card.dat so number of events is as desired, beam energies are correct

./bin/madevent, running delphes